Asset Encumbrance and Bank Risk: Theory and Evidence

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Abstract

Asset encumbrance restricts bank's ability to transfer or realize its assets. Asset encumbrance has recently become a much-discussed subject and policymakers have been actively addressing what some consider to be excessive levels of encumbrance. Despite its importance, the phenomenon remains poorly understood. We provide a simple theoretical model that highlights the implications of asset encumbrance for financial stability. We show that the effect of encumbrance depends on rates of over-collateralization faced by the banks. With low haircuts, asset encumbrance is negatively associated with bank credit risks as secured funding minimizes bank's exposure to liquidity shocks. With high haircuts, encumbrance can exacerbate liquidity risks due to structural subordination effect and, hence, can be positively associated with bank credit risk premiums. We next use a hand-collected dataset on the levels of asset encumbrance of European banks and provide further empirical evidence supporting the predictions of the model. Our empirical results point to the existence of a negative association between CDS premia and asset encumbrance. Still, certain bank-level variables play a mediating role in this relationship. For banks that have high exposures to the central bank, high leverage ratio, or are located in southern Europe, asset encumbrance is less beneficial and could even be detrimental in absolute terms.

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1 Introduction

As of June 2011, Dexia, a Franco-Belgian bank, reported a strong Tier 1 Capital Ratio of 11.4%.[1] Out of the 91 institutions analysed in the European Banking Authority (EBA) stress tests, Dexia came joint 12th, with a forecast Core Tier 1 capital ratio of 10.4% under the adverse stress scenario.[2] From a liquidity standpoint, the bank had built up a buffer of €88bn in liquid securities, had decreased short-term funding needs by €47bn and its short-term ratings had been reaffirmed as investment grade by the main credit rating agencies. But just three months later, in October 2011, Dexia was partly nationalised by the Belgian and French governments. Several commentators highlighted the high levels of "encumbered" assets as the key factor precipitating its move into government arms.[3,4]

Asset encumbrance refers to the existence of financial bank balance sheet assets being subject to arrangements that restrict the bank's ability to freely transfer or realise them. Bank assets become encumbered when these are used as collateral to raise funding, for example in repurchase agreements (repos) or in other collateralised transactions such as asset-backed securitisations, covered bonds, or derivatives.[5] In the particular case of Dexia, more than €66bn of its €88bn buffer securities were encumbered through different secured funding arrangements, particularly with the European Central Bank (ECB), and were therefore unavailable for obtaining emergency funding.

Policymakers are acting decisively in order to address what some consider to be excessive levels of asset encumbrance. Some jurisdictions have introduced limits on the level of encumbrance (Australia, New Zealand) or ceilings on the amount of secured funding or covered bonds (Canada, US), while others have incorporated encumbrance levels in deposit insurance premiums (Canada). Several authors have proposed linking capital requirements to the banks asset encumbrance levels or establishing further limits to asset encumbrance as a back-stop (Helberg and Lindset (2014); IMF (2013); Juks (2012)). As part of the Basel III regulatory package, the

[1] See Dexia 2Q & 1H 2011 Results and Business Highlights Presentation, 4 August 2011

[2] The Core Tier 1 ratio represents the ratio of very high quality capital (shareholders capital and reserves) to risk-weighted assets (RWA). The Tier 1 capital ratio includes, in addition to Core Tier 1 capital, other perpetual capital resources such as subordinated debt instruments with conversion features and is also expressed as a fraction of RWA.

[3] See e.g. Financial Times, "Bank collateral drying up in rush for security", October 2011.

[4] More recently, in June 2017, Banco Popular was put into resolution by the European Single Supervisory Mechanism (SSM) and was acquired by Banco Santander for a symbolic amount of €1. Yet, as of year-end 2016, the Spanish bank Banco Popular reported a Tier 1 capital ratio of 12.3% and had passed the EBA stress tests undertaken in 2016 with a solid margin. However, nearly 40% of its total balance sheet assets were encumbered as of December 2016.

[5] Collateralisation is a common method of mitigating counterparty credit risk in derivative markets through the provisioning of margin.

Net Stable Funding Ratio (NSFR), an additional minimum liquidity requirement of the LCR will be introduced in 2018. The NSFR heavily penalises asset encumbrance by requiring substantial amounts of stable funding to finance encumbered assets. In Europe, regulatory reporting and disclosure requirements have been introduced and all institutions are required to incorporate asset encumbrance within their risk management frameworks. The Dutch National Bank has even committed to "keeping encumbrance to a minimum" (De Nederlandsche Bank (2016)).

Despite the importance of asset encumbrance, the phenomenon remains poorly understood. In this paper, we provide a simple theoretical model to understand bank asset encumbrance and its implications for financial stability. We also demonstrate empirical evidence consistent with the predictions of the model.

For the theoretical analysis, we employ the standard approach of modeling bank liquidity risk: when faced with creditors' run, the bank can sell a part of its assets to meet the withdrawal. However, the bank can still fail if it does not have a sufficient amount of unencumbered assets to meet the debt holders' demand. To finance its long-term asset, the bank can issue secured or unsecured debt. Secured funding is safer than the unsecured one as it provides investors with protection in the form of collateral, and thus the holders of secured debt do not withdraw the cash prematurely. In this respect, secured funding is also more stable than unsecured one.

In our model, asset encumbrance has two opposing effects on liquidity risk. On the one hand, when the level of asset encumbrance is high, the bank has fewer unencumbered assets available for the case of emergency. In other words, if the unsecured debt holders decide to withdraw their money, the bank has less liquidity to meet their demand — this is the *structural subordination* effect of asset encumbrance on unsecured debt holders. On the other hand, with higher encumbrance, the bank has fewer liabilities subject to run and, hence, lower liquidity risk. We refer to the former as the *stable funding* effect of asset encumbrance. Overall, which effect dominates depends crucially on the rates of over-collateralization, i.e. on the haircuts.

Our main finding is that when the over-collateralization of secured funding is low, the stable funding effect dominates the adverse effect of structural subordination. With low rates of over-collateralization, the bank finds it optimal to use the secured sources: secured funding leaves a relatively large amount of unencumbered assets to satisfy the potential liquidity demand of unsecured creditors. This implies that the bank would be able to face stronger liquidity shocks: asset encumbrance can reduce the bank's liquidity risk. As a result, unsecured debt holders would require a lower interest rate to compensate for bank's default risk. However, we also find that when the over-collateralization of secured funding is sufficiently high, the structural subordination effect dominates the one of stable financing. With high haircuts, the bank can raise a smaller amount of secured funding by pledging the same amount of asset: this reduces the stable funding effect. On the other hand, to raise a given amount of secured financing, the bank needs to pledge more asset to secured debt holders, which enforces the adverse structural subordination effect. In this case, asset encumbrance increases bank's liquidity risk and, therefore, unsecured debt holders demand a higher interest rate.

The model generates predictions that can be verified in the data. First, contrary to the conventional wisdom, for financially strong banks, asset encumbrance level is predicted to be negatively correlated with the premium of unsecured debt. Second, for banks with over-collateralization, encumbrance can be positively correlated with the premium on unsecured debt. We next bring these predictions to the data and investigate the association of asset encumbrance and credit risk spreads empirically. To do so, we build a novel dataset using information provided in the asset encumbrance disclosures published for the first time throughout 2015 by European banks, following a set of harmonised definitions provided by the EBA (EBA (2014)). In a cross-section of banks, we find that institutions with higher encumbrance levels have lower CDS spreads — i.e. bank risk seems to be negatively associated with asset encumbrance. We also find that some variables play a mediating role in the relationship between asset encumbrance and bank risk. For banks with a high reliance on central bank funding and high levels of liquid assets, such as Dexia, or with a high leverage ratio and high levels of impaired loans, such as Banco Popular, or for banks located in Southern Europe (GIIPS), asset encumbrance is less beneficial and could even be detrimental in absolute terms.[6] These findings imply that regulators need to be cautious when assessing asset encumbrance levels and leaping to across-the-board conclusions about its effects.

Until now, the literature on asset encumbrance and bank financial instability is still nascent. Our paper is closely related to Ahnert, Chapman, et al. (2017). The main modeling difference with Ahnert, Chapman, et al. (2017) is the investors' preferences. In Ahnert, Chapman, et al. (2017), there is no safety premium for the infinitely risk-averse investors. Therefore, secured funding is more expensive than unsecured funding, which implies that the amount of unsecured funding is fixed. In their model, asset encumbrance only has the structural subordination effect on unsecured debt holders. As a consequence, Ahnert, Chapman, et al. (2017) predict that bank's asset encumbrance level is positively correlated with the premium of unsecured debt. In our paper, on the contrary, banks can use the secured financing to replace

[6] In the demise of Banco Popular (see footnote 4), the bank had high levels of asset encumbrance and of impaired loans. As of December 2016, almost 15% of Popular's loan portfolio was non-performing compared to a European average of 5.1%. Its Basel III Leverage Ratio was also high (5.31% compared to a weighted average for European banks of 5.2% as per EBA (2017)).

unsecured funding, which generates the stable funding effect. Thus, we predict that bank's asset encumbrance level can be negatively correlated with the premium of unsecured debt. This result also differs from Matta and Perotti (2015), who show that more secured funding necessarily increases the frequency of runs. Gai and Chapman (2017) also study the implications of bank asset encumbrance for financial instability. However, in their model, bank's funding structure is exogenously given rather than endogenously chosen by the bank.

Our paper contributes to the literature on secured debt and more generally firms' debt structure choices. In the context of corporate finance, there is an extensive literature on secured financing. Theoretically, the possible explanations of the use of secured debt include mitigating agency conflicts between shareholders and creditors (C. W. Smith and Warner (1979), Stulz and Johnson (1985)), addressing the information asymmetries between the lender and borrower (Chan and Thakor (1987), Berger and Udell (1990), Thakor and Udell (1991)). These papers have different predictions for the use of secured debt. For instance, according to C. W. Smith and Warner (1979), Stulz and Johnson (1985), high-quality firms may use secured debt to avoid investment inefficiencies. On the other hand, Chan and Thakor (1987), Berger and Udell (1990), Thakor and Udell (1991) predict that secured debt is used predominantly by low quality firms. A recent interesting paper by Donaldson, Gromb, and Piacentino (2017) focus on the role that collateral can serve as a commitment device for the firm. In their model, a firm can not commit not to expropriate the unsecured creditors. Creditors thus require collateral for protection against possible expropriation by collateralized debt in the future. However, collateralized borrowing has a cost since it can constrain firm's future borrowing and investment. Unlike these papers, our paper emphasizes a total different friction of collateralized borrowing: the interaction between collateralized borrowing and bank's unsecured creditors as well as liquidity risk, which is banking specific.

There is also a vast literature on empirical research of secured debt. However, the empirical research on use of secured financing is less decisive. For instance, Julio, Kim, and Weisbach (2007) find that the vast majority of public debt issues are unsecured, while Nini, D. C. Smith, and Sufi (2009) document that 65 percent of a large sample of private credit agreements between 1996 and 2005 were secured. In the context of banking, Di Filippo, Ranaldo, and Wrampelmeyer (2016) find that that banks with higher credit risk are able to offset a reduction of unsecured borrowing with secured loans, consistent with theories of lender moral hazard. Unlike Di Filippo, Ranaldo, and Wrampelmeyer (2016), we find that better banks may use more secured debt. Besides, our paper focuses on the relationship between asset encumbrance level and the premium of unsecured debt holders. Therefore, our paper can explicitly tackle the issue of structural subordination missing in Di Filippo, Ranaldo, and Wrampelmeyer (2016).

The rest of the paper is organized as follows. Sections 2 and 3 describe the model setup and bank liquidity risk. In Section 4 we present the theoretical results for the case when collateral haircuts are low. Section 5 is devoted to the discussion of theoretical implications of high rates of over-collateralizatoin. In Section 6 we provide empirical evidence supporting model predictions. Section 7 concludes.

2 Model Setup and Bank Risk

2.1 Bank and Investors

Consider a risk-neutral bank and a continuum of investors. At $t = 0$, the bank has access to a profitable project that needs one unit of cash. The bank has no cash at hand, so it needs to raise funds from investors. The bank's project generates a random return $\theta \geq 0$ at $t = 1$ and a fixed return $k < 1$ at $t = 2$. The random return θ follows a uniform distribution with $\theta \sim U[0, \bar{\theta}]$. For notational simplicity, we sometimes denote the (uniform) cumulative distribution function of θ by $F(\theta)$. As $k < 1$ and θ can be zero, the bank is subject to insolvency risk. The bank has limited liability.

We assume that the bank issues long term demandable debt (see, e.g., Diamond and Dybvig (1983), Diamond and Rajan (2001), Calomiris and Kahn (1991) for microfoundations). That is, investors can withdraw their money at $t = 1$, before the project matures. The bank can use θ and the proceeds from selling part of the fixed second-period returns k prematurely, at a per-unit fire-sale price of $\phi < 1$. Equivalently, at $t = 1$, there is a bond market where the bank can sell riskless bonds which promise one unit of cash at $t = 2$, at a price $\phi < 1$.[7] Here $1 - \phi$ reflects the fire-sale discount in a market with limited liquidity. Since the project's payoff at $t = 2$ is k, the bank can sell bonds up to a maximum of k. The bank fails if the amount withdrawn exceeds its liquid assets at $t = 1$. Thus, as in Allen and Gale (1994), the bank is subject to liquidity risk.

There are two types of investors. Some investors are risk neutral and demand a minimum expected return of $1 + \gamma$, with $\gamma > 0$. The others are infinitely risk averse and willing to lend if and only if the debt is absolutely safe. They demand a minimum return of 1, which is lower than the expected return demanded by risk neutral investors. This assumption reflects some investors' strong preferences for safety.[8] We assume that the wealth of each group investors is

[7]See Freixas and Rochet (2008) for the same setup.

[8]See (Gorton, Lewellen, and Metrick (2012); Krishnamurthy and Vissing-Jorgensen (2012)) for empirical evi-

sufficiently large such that the bank's financing decision will not be constrained by each group of investors' wealth.

2.2 Asset Encumbrance

The bank can raise funding from secured debt holders or unsecured debt holders. Denote by s the money raised through secured debt, and $1 - s$ the money raised through unsecured debt. Since infinitely risk averse investors demand a lower expected return, it is optimal for the bank to raise secured funding from this group of investors. To raise secured funding from infinitely risk averse agents, the bank needs to pledge assets so that these investors are repaid fully and unconditionally. In our model, the bank can pledge a fraction of the project's payoff at $t = 2$, up to a maximum of k. The bank's return θ at $t = 1$ cannot be pledged because it is random with the lowest return of 0. Hence, from now on, we refer to k as the available collateral of the bank.

For each unit of secured funding, the bank needs to pledge $1 + h$ units of collateral, where h reflects the haircut. We consider two distinct levels of haircuts for secured funding. In the first, the haircut is totally determined by the liquidity of the collateral in the market, that is, h is such that $(1 + h)\phi = 1$. If required, the bank can sell the collateral and recover $(1 + h)\phi = 1$ for each unit of secured funding at $t = 1$. In the second case, there are other costs of collateral liquidation, so that $(1 + h)\phi > 1$, reflecting for instance the time it takes to find a buyer of the collateral in the over-the-counter market, the legal costs of seizing the collateral or the fact that investors value the collateral less than the bank. Banks with low quality collateral, such as risky or illiquid bonds, may find it more difficult to find a buyer. Haircuts may also be higher in crisis periods.

The assets pledged to secured debt holders as collateral are encumbered, so they cannot be sold at $t = 1$ to meet unsecured debt holders' withdrawals. In the event of a bank run, secured debt holders are able to seize the encumbered assets. However, because of full collateral protection, they have no incentive to withdraw money in the interim period. Unsecured investors, on the contrary, in case of bank failure will share the unencumbered collateral and θ on a pro-rata basis. From now on, we refer to s as the level of bank asset encumbrance.

dence, and (Stein (2012); Caballero and Farhi (2013); Gennaioli, Shleifer, and Vishny (2012)) for similar modeling assumptions.

2.3 Bank's Risk

We now identify the two effects of asset encumbrance on bank risk, which we name stable funding and structural subordination effects. Throughout this section, we treat the level of asset encumbrance, s, and the face value of a unit of unsecured debt, D_u, as exogenously given. Since unsecured debt holders demand a minimum return of $1+\gamma$, we must have that $D_u \geq 1+\gamma > 1$. Since secured debt is absolutely safe, the face value of a unit of secured debt is $D_s = 1$, which is equal to the minimum return demanded by infinitely risk averse investors.

The bank is exposed to insolvency risk. The bank is insolvent if and only if the total value of bank's asset is inferior to the debt obligations:

$$\theta + k < s + (1-s)D_u.$$

As $k < 1$, θ can be zero, and $s + (1-s)D_u > 1$, there exists a critical solvency return θ^{**} such that the bank is solvent if and only if:

$$\theta > \theta^{**} \equiv s + (1-s)D_u - k. \tag{1}$$

The bank is also exposed to liquidity risk. At $t = 1$, unsecured debt holders can decide whether to withdraw or not. The bank can use its period-1 proceeds θ as well as proceeds from the sale of unencumbered assets, $k - (1+h)s$ at a price of $\phi < 1$ to meet the withdrawal. But, if all the unsecured debt holders choose to withdraw, the bank will fail from a run on the bank at $t = 1$ if the bank's available liquidity is inferior to the investors' withdrawals:

$$\theta + (k - (1+h)s)\phi < (1-s)D_u.$$

Hence, we can define a critical liquidity return for the bank θ^*:

$$\theta^* \equiv (1-s)D_u - (k - (1+h)s)\phi \tag{2}$$

As $\theta^* > \theta^{**}$, the range of θ can be split into three regions. The bank is insolvent if $\theta < \theta^{**}$, solvent but possibly illiquid if $\theta^{**} < \theta < \theta^*$, and liquid and solvent if $\theta > \theta^*$. The intermediate region spans multiple equilibria. In one of them, all unsecured debt holders withdraw and the bank fails. In another equilibrium, all unsecured debt holders choose not to withdraw and the bank survives. For simplicity, we assume that the bad equilibrium will always be chosen, so that the bank fails if $\theta^{**} < \theta < \theta^*$. In this region, the bank is solvent, but fails because of the unsecured investors' self-fulfilling concern that all the other unsecured debt holders withdraw.[9] As $\theta \sim U[0, \bar{\theta}]$, the bank fails at $t = 1$ with probability $\theta^*/\bar{\theta}$. Clearly, the higher the liquidity cutoff θ^*, the higher the bank's liquidity risk.

Notice that an increase in asset encumbrance, s, has two effects on bank's liquidity risk, θ^*. On the one hand, as s increases $(1 - s)D_u$ decreases, which implies that the bank needs less liquidity to face a potential liquidity shock at $t = 1$. This is the *stable funding effect* of secured financing. On the other hand, as s increases, $(1 + h)\phi s$ increases, which implies that the amount of unencumbered assets available to the unsecured debt holders is lower. This is the *structural subordination effect* of secured funding. If $(1 + h)\phi = 1$, the marginal effect of s on $(1 - s)D_u$ exceeds the marginal effect on $(1 + h)\phi s$ because $D_u > 1$. Therefore, θ^* decreases in s. But with larger h, the negative effect of structural subordination is greater and thus the relative importance of the two effects may be reversed.

3 Optimal Asset Encumbrance and Overcollateralization

In this section, we determine the bank's optimal level of asset encumbrance, as well as the resulting unsecured funding costs. We consider low versus high over-collateralization: when h is such that $(1 + h)\phi = 1$ and when h is such that $(1 + h)\phi > 1 + \gamma$. In each case, our analysis unfolds in three steps. First, we study how asset encumbrance affects bank's liquidity risk θ^* and the expected bank's profits Π for an exogenous s. Second, we allow the bank to choose the level of asset encumbrance, s^*, so as to maximize its expected profits. Third, we study the relationship between asset encumbrance level and unsecured interest in a cross section of banks with different available collateral k.

The endogenously chosen face value of unsecured debt depends on the probability of failure θ^*. Given s, the break-even condition for unsecured debt holders is indeed given by:

$$\int_0^{\theta^*} [\theta + (k - (1 + h)s)\phi] dF(\theta) + \int_{\theta^*}^{\bar{\theta}} (1 - s)D_u dF(\theta) = (1 - s)(1 + \gamma) \tag{3}$$

The first term in the left hand side is unsecured debt holders' expected return if the bank fails from a run at $t = 1$. Unsecured debt holders share θ, as well as all the discounted unencumbered collateral, $(k - (1 + h)s)\phi$, on a pro-rata basis. The second term in the left hand side is unsecured

[9] In principle, we could also use the global games approach of Goldstein and Pauzner (2005), to select a unique equilibrium. We work with an exogenously chosen equilibrium for tractability. And we can generalize the model to allow for multiple equilibrium. In the more general case, when $\theta < \theta^*$, the bank fails from bank run with exogenous probability q, and survives with probability $1 - q$. Our results still hold in this more general case.

debt holder's expected return if the bank survives from the run. In this case, unsecured debt holders are fully paid at $t = 2$. The right hand side is the opportunity cost of unsecured debt holders' funding.

Consider next the bank's choice of funding structure to maximize its expected profit. Since bank has limited liability, the bank's objective function is:

$$\Pi = \int_{\theta^*}^{\bar{\theta}} [\theta + k - s - (1-s)D_u] dF(\theta) \tag{4}$$

subject to investors participation constraint (3). When $\theta < \theta^*$, the banks fails at $t = 1$ and shareholders receive 0. When $\theta > \theta^*$, the bank survives and the payoff of the bank's assets is $\theta + k$. At $t = 2$ the bank pays s to secured debt holders and $(1-s)D_u$ to unsecured investors. Clearly, Π is a function of θ^*, D_u and s. As we have shown before, both θ^* and D_u are determined by s. Therefore, Π is determined by s.

3.1 Low Rates of Overcollateralization

As shown in (3), the face of value of unsecured debt D_u depends on the bank's liquidity risk θ^*. Using the definition of θ^* in (2), one can express θ^* as a function of s. We have

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1 + \gamma - s\gamma - \frac{k}{1+h})} \tag{5}$$

The following proposition characterizes the effect of asset encumbrance on bank's liquidity risk.[10]

Proposition 1. *Bank's liquidity risk θ^* is strictly decreasing in the level of asset encumbrance s, and strictly increasing in the level of over-collateralization h.*

Proposition 1 may seem counterintuitive. Indeed, as asset encumbrance increases, the bank has less liquidity available to meet the withdrawal of unsecured debt holders; hence, it is more likely to fail because of liquidity shocks. But, higher levels of asset encumbrance also imply that the bank raises more funding from secured investors who never run the bank. Other things equal, when unsecured debt obligations decrease, the bank needs less cash to meet debtholders' withdrawals. This is the stable funding effect of asset encumbrance, in the sense that the bank replaces the unstable secured financing with the stable secured funding. As explained earlier, if $(1+h)\phi = 1$, the marginal effect of s on $(1-s)D_u$ exceeds the marginal effect on $(1+h)\phi s$

[10]The proofs of all results are in the Appendinx A.

because $D_u > 1$. This implies that when the haircut is low, the negative structural subordination effect is dominated by the positive stable funding effect. Therefore, asset encumbrance reduces bank's liquidity risk. Moreover, as h increases, the negative effect is stronger and the positive effect is weaker, thus bank's liquidity risk is higher.

The following proposition shows the effect of asset encumbrance on bank's expected profit.

Proposition 2. *The bank's expected profit* Π *is strictly increasing in the level of asset encumbrance* s*.*

Asset encumbrance affects bank's expected profit in two ways. First, since secured funding is a cheaper source of finance, higher asset encumbrance reduces bank's overall funding cost: conditional on success, the bank receives larger residual payoffs. Second, asset encumbrance reduces bank risk, θ^*. Both effects are positive.

From proposition 2, the bank should set the level of asset encumbrance as high as possible. We now determine the optimal level of encumbrance, as well as the resulting face value of unsecured debt D_u and the bank's liquidity risk θ^*. Note that a bank could choose s as 0. However, generally, it is not the optimal choice of the bank. We collect these results in the following proposition.

Proposition 3. *As the amount of available collateral* k *increases: (i) The level of asset encumbrance,* s^**, which is given by* $s^* = \frac{k}{1+h}$ *increases. (ii) The interest rate of unsecured debt holders,* D_u*, decreases.*

The intuition of proposition 3 is as follows. A bank with more available collateral is able to raise more secured funding. As we have shown before, asset encumbrance reduces bank's liquidity risk. Therefore, unsecured debt holders require a lower face value of debt to compensate for the risk of bank failure.

Hypothesis 1. *In a cross-section of banks with an endogenously chosen level of asset encumbrance, bank's unsecured funding cost* D_u *is negatively correlated with bank's level of asset encumbrance* s*.*

Since both asset encumbrance and interest rate of unsecured debt are observable in the data, we can test this hypothesis.

Now, we can use a numerical example to compare the asset encumbrance level and unsecured debt interest rate in a cross-section of banks with different available collateral k. Here we set $\bar{\theta} = 1, \phi = 0.9, \gamma = 0.05, h = 0.11$. As we can see from Figure 3, there is a negative relationship between the asset encumbrance and premium of unsecured debt. The higher the asset encumbrance, the lower the interest rate of unsecured debt.

[Figure 1]

[Figure 2]

[Figure 3]

3.2 High Rates of Overcollateralization

In this section, we derive bank's optimal asset encumbrance, when $h > \phi^{-1} - 1$. We can show that

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}((1+\gamma)(1-s) - k\phi + (1+h)\phi s)} \tag{6}$$

The following proposition characterizes the effect of asset encumbrance on bank's liquidity risk when h is sufficiently high.

Proposition 4. *If the haircut of secured funding h is sufficiently high such that $(1+h)\phi > 1+\gamma$, bank's liquidity risk is increasing in the level of asset encumbrance s, and strictly increasing in the level of over-collateralization h.*

Proposition 4 is quite intuitive. As we mentioned before, asset encumbrance affects bank's liquidity risk in two ways: it reduces the risk due to the stability of secured funding and, at the same time, increases it by amplifying structural subordination of the unsecured lenders. When the haircut of secured funding is relatively high, the bank needs to pledge more asset to raise secured funding. On the one hand, the bank can raise less secured funding by pledging the same amount of asset, which reduces the stable funding effect. On the other hand, to raise a given amount of secured funds, the bank needs to pledge more asset to secured debt holders, which implies that the negative structural subordination effect on unsecured debt holders is even larger. When the haircut of secured funding is sufficiently high, the negative structural subordination effect of asset encumbrance will eventually dominate the stable funding effect. In this case, asset encumbrance increases bank's liquidity risk. From Figure 4, we can see that with increasing level of asset encumbrance the blue line is steeper than the red one, which implies that the decline of liabilities subject to run is slower than the decrease of the unencumbered asset.

[Figure 4]

Next, we study the bank's optimization problem. The bank chooses the level of asset encumbrance s to maximize its expected profit. The bank's objective function is the same as before (eq. (4)). However, with new parameter values, the bank faces a trade-off when choosing asset encumbrance. On the one hand, secured funding is cheaper than unsecured one. On the other hand, as is shown in proposition 4, a higher level of asset encumbrance increases bank's liquidity risk, so the bank is more likely to fail at $t = 1$, and unsecured debt holders may demand a higher interest rate. This trade-off determines bank' optimal level of asset encumbrance.

This result differs from that in proposition 3, where bank' optimal level of asset encumbrance is a corner solution. The difference arises from the level of the haircut h relative to the fire-sale discount ϕ. When h is low, over-collateralization is low: the bank needs to ensure that the excess collateral covers only the potential losses of asset liquidation. Since in this case, assets allow for high level of secured funding, the negative effect of asset encumbrance on bank's liquidity risk is dominated by the positive effect of stable liabilities. Alternatively, when h is high, over-collateralization is also high, so the negative effect of asset encumbrance on bank's liquidity risk dominates the positive impact of stable financing.

If $(1 + h)\phi > 1 + \gamma$, it is possible that in a cross-section of banks asset encumbrance is positively associated with the premium of unsecured debt. k can affect θ^* in two ways. First, through the direct effect on $k\phi$, when k is larger, the bank's liquidity risk is lower. This is intuitive, since a bank with more collateral is less likely to fail from bank run. Second, banks' choice of s may depend on k, which has an indirect effect on θ^*. Since $(1 + h)\phi > 1 + \gamma$, if a bank with larger k chooses higher s, then the indirect effect of k on θ^* would be negative, which may lead to higher unsecured interest rate.

Unfortunately, we are not able to provide the analytic results here. We illustrate this result in the following numerical example where we set $\bar{\theta} = 1, \phi = 0.9, \gamma = 0.05, h = 0.25$.

[Figure 5]

[Figure 6]

[Figure 7]

The implications of the above analysis for observable data can be summarized as follows:

Hypothesis 2. *In a cross section of banks with endogenously chosen asset encumbrance level, it is possible that bank's unsecured funding cost D_u is positively correlated with bank's level of asset encumbrance s.*

3.3 Comments on the Model

In our model, there are two departures from Modigliani and Miller.

First, in our model, some investors have preference for secured debt, which makes secured debt relatively cheaper for the bank. In contrast, in Modigliani and Miller, investors have no preference for the safety of the security. If we change the first assumption so that investors have no preference for safety, the asset encumbrance would be irrelevant. To see this result, note that

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1 + \gamma - s\gamma - k\phi)} \tag{7}$$

If $\gamma = 0$, θ^* is independent of s. Therefore, the level of bank asset encumbrance will not affect bank's liquidity risk.

Second, in the model, banks are subject to liquidity risk, and conditional on bank run, there is liquidation cost for the bank. The funding structure will affect bank's liquidity risk, which is a friction absent in Modigliani and Miller. If we assume that there is no liquidation cost for the bank, i.e., $\phi = 1$, clearly the bank will try to maximize the level of asset encumbrance to take advantage of the lower funding cost of secured lending. Similarly, if $h = 1$, then secured debt dominates unsecured debt in terms of every aspect since secured debt is both more stable and cheaper. The bank will maximize the use of secured debt.

We now turn to empirical evidence on the relationship between asset encumbrance and credit risk premiums of banks.

4 Empirical evidence

In this section, we provide empirical evidence supporting the theoretical model described above. To do this, we run a set of regressions aimed to capture the association between the observable levels of asset encumbrance and bank credit risk. We further analyze heterogeneity of this relationship related to bank characteristics. This second part of the analysis is thought to show that the relationship between credit risks and encumbrance levels crucially depends on the financial conditions of a bank.

4.1 Data and Descriptive Statistics

To implement the regression analysis, we extract data from the risk disclosures of banks, including information on encumbered assets, unencumbered assets, off-balance sheet (OBS) collateral received and available for encumbrance, OBS collateral received and re-used and matching liabilities (the liabilities or obligations that give rise to encumbered assets) as of year-end 2014. We complement the disclosure data with data on total assets and equity extracted from Bankscope to compute the asset encumbrance ratios for each institution.

Our main dependent variable in the multivariate regressions is a measure of bank risk represented by banks' CDS spreads as of year-end 2015. CDS spreads are widely considered to be a good indicator of bank risk and can be a proxy for bank unsecured funding costs (see Babihuga and Spaltro (2014); Beau et al. (2014 Q4)). We use implied rather than market-based spreads because only the largest global institutions are involved in CDS issuance. For most banks, Fitch Solutions determines the implied spreads on a daily basis using a proprietary model that includes, as inputs, banks' financial fundamental information, distance-to-default information derived from the equity market, and other market variables. In line with the existing literature, we focus on five-year senior spreads since these contracts account for 85% of the market and are highly liquid. Data is provided by Fitch Solutions and extracted from Bankscope.

Computing asset encumbrance measures at the bank level is not straightforward since accounting data provides limited information to infer the amount of banks' encumbered assets, unencumbered assets and matching liabilities. Accounting statements are accompanied by disclosures which try to shed light on the amount of assets that are collateralising transactions but, as noted by the EBA: "existing disclosures in International Financial Reporting Standards (IFRS) may convey certain situations of encumbrance but fail to provide a comprehensive view on the phenomenon" (EBA (2014)). For this reason, the EBA introduced new guidelines in 2014 proposing the requirement to disclose asset encumbrance reporting templates. EBA guidelines do not constitute a regulatory requirement and, although most did, not all of the European institutions disclosed such information.

Furthermore, there is currently no consensus as to how asset encumbrance shall be measured and different measures have been proposed. We focus on the three key ratios being used by policymakers. The computation of each ratio is illustrated in figure 8.

[Figure 8]

Hence, the asset encumbrance ratios (AERs) capture the amount of encumbered assets as a proportion of total assets. There are two variations:

- The ratio of *encumbered assets to total assets*, which captures the overall proportion of balance sheet assets that have been encumbered. This ratio has been used by the Bank of England and the European Systemic Risk Board (ESRB) to undertake analysis of the UK and European banking sectors respectively (Beau et al. (2014 Q4); ESRB (2013)). We denote it as AER1.

- The ratio of *encumbered assets and other collateral received and re-used to total assets and total collateral received*, which captures the overall proportion of encumbered balance sheet assets as well as off-balance sheet collateral. This ratio is used by the EBA to undertake their risk assessment of the European banking system and to apply more comprehensive regulatory reporting requirements (EBA (2016)). We denote this ratio as AER2.

The third ratio focusses instead on unencumbered assets:

- The ratio of *unencumbered assets to unsecured liabilities* (UAUL), which captures the proportion of assets which are not subject to collateral agreements as a proportion of unsecured creditor's claims and provides an indication of the amount of structural subordination of unsecured creditors. According to a report from the Bank of International Settlements' Committee on the Global Financial System (CGFS (2013)), the UAUL ratio is the most appropriate measure of asset encumbrance.

As opposed to AER1 and AER2, UAUL is a measure of how many assets are available to unsecured creditors under insolvency, and should therefore capture the structural subordination of unsecured creditors more directly than AER1 and AER2. Since UAUL is measured relative to unsecured funding, this ratio would be unable to capture low levels of unencumbered assets relative to the total assets of banks that rely heavily on capital or secured funding. As opposed to AER2, AER1 and UAUL do not capture encumbrance arising from off-balance sheet activities.

For UAUL, we use a slightly modified version which we denote as AUAUL (Adjusted UAUL), calculated as

$$\text{AUAUL}_i = \frac{\max(\text{UAUL}) - \text{UAUL}_i}{\max(\text{UAUL}) - \min(\text{UAUL})},$$

where UAUL_i is bank's i ratio of unencumbered assets to unsecured liabilities and $\max(\cdot)$ and $\min(\cdot)$ return, correspondingly, the sample maximum and minimum of their arguments. This adjustment facilitates comparisons with AER1 and AER2 by ensuring that higher encumbrance is associated with a higher AUAUL and that its values fall between 0 and 1.

Explanatory variables include, in addition to the asset encumbrance measures, CAMEL and control variables. We follow Chiaramonte and Casu (2013) to select the following CAMEL variables:

- Capital Adequacy:
  - The Tier 1 capital ratio, which represents the ratio of high-quality capital (shareholders' capital, reserves and other perpetual capital resources such as subordinated debt), divided by risk-weighted assets (RWA).
  - The leverage ratio, which is calculated as the fraction of common equity to total assets and reflects the level of indebtedness of a firm.
- Liquidity:
  - The net loans to deposits and short-term funding ratio, which is a measure of structural liquidity. A lower value of the ratio means the bank relies to a greater extent on more stable deposit funding, as opposed to wholesale funding, to finance its loan book.
  - The liquid assets to total assets ratio, which measures the amount of liquid assets that the bank holds and that could be converted into cash to withstand a liquidity stress event.
- Quality of assets:
  - The ratio of loan-loss reserve to gross loans, which measures the quality of the loan portfolio by indicating the proportion of reserves for losses relative to the banks' loan portfolio.
  - The ratio of unreserved impaired loans to equity, which is another indicator of the quality of the loan portfolio but expressed relative to common equity. It is also known as the "capital impairment ratio".
- Earnings potential:
  - The return on equity ratio (ROE), which measures the banks income-producing ability as reflected by its net income relative to the banks common equity.
  - The return on assets ratio (ROA), which is an indicator of the return on a firms investments and is calculated by dividing the banks net income over its total assets.

Control variables include bank size (measured by the natural logarithm of total assets), central bank exposure to total assets and off-balance sheet exposure to total assets. We include dummy variables to differentiate the business model of the institution using three categories: "Commercial banks and Bank holding companies (BHC)", "cooperative and savings banks" and "other banks". We also include a dummy variable to identify which banks are investment grade. We use implied ratings in order to avoid compromising the sample size, in a similar fashion to CDS spreads. Implied ratings are provided by Fitch Solutions and derived from proprietary fundamental data. These provide a forward-looking assessment of the stand-alone financial strength of a bank and are categorised according to a 10-point rating scale from A to F where A denotes the maximum creditworthiness, with four interim scores (A/B, B/C, C/D and D/E).

Our final data sample includes institutions with total assets above €1bn for which CDS spreads, asset encumbrance, CAMEL and control variables are available, resulting in 367 banks.

Table 1 presents the summary statistics of the variables of study. The mean values of AER1, AER2 and AUAUL are 0.13, 0.14 and 0.60 respectively. Note that there is a wide disparity across banks in our sample. AER1 and AER2 present standard deviations of 0.11 and 0.12 respectively. Although the standard deviation of AUAUL is lower (0.08), the mean and the original standard deviation of UAUL are 1.06 and 0.15.

[Table 1]

[Table 2]

Table 2 presents the correlation matrix of encumbrance ratios. AER1 and AER2 present a high correlation of 0.97 which is expected given their similar construction with the only difference being the inclusion of off-balance sheet collateral in AER2. The correlation coefficients of AUAUL with AER1 and AER2 are 0.39 and 0.36 respectively.

Figure 9 shows the mean ratio levels of AER1 (blue, left scale) and AUAUL (green, right scale) for those countries with more than one observation. The countries are shown in four groups corresponding to GIIPS, Nordic countries, core countries including Austria, Belgium, Germany, France, UK, Luxembourg and the Netherlands, and other European countries such as the Eastern European countries and Malta. Results show a wide disparity in mean encumbrance levels across countries. All the GIIPS countries presenthigher mean encumbrance ratios than the sample average, as do Nordic countries such as Denmark and Sweden. Denmark, in particular, presents the highest mean ratio of all countries in the sample. Nordic countries have a long tradition of covered bond issuance, which may help explain these results. Of the remaining countries, Belgium, France and the UK present higher mean encumbrance levels than the overall sample average. Belgium, Malta, Netherlands and the UK present higher mean values of AUAUL than the sample mean. Luxembourg and some of the countries classified as "other" such as Bulgaria, Poland and Malta present the lowest values of AER1 but also the largest differences between AUAUL and AER1.

[Figure 9]

Table 3 shows the mean levels of the two asset encumbrance ratios across rating categories. Banks within the most extreme categories, A/B and E/F, present the lowest mean AER1 and AER2 ratios of all categories. For AUAUL, it is banks in categories D/E and E/F that present the lowest mean values.

[Table 3]

As shown in the same table, mean encumbrance levels tend to increase with bank size, measured in terms of total assets, across all ratios. Since securitisations involve substantial costs, mostly of a fixed nature, these should be particularly costly to issue for smaller banks (Adrian and Shin (2010); Carbó-Valverde, Marques-Ibanez, and Rodrguez-Fernández (2012); Panetta and Pozzolo (2010)).

Table 3 also reports the mean ratio levels by type of institution. We distinguish between "commercial banks and bank holding companies (BHC)", "cooperative banks", "savings banks" and "other banks", including mortgage banks and pure investment banks. Savings banks show the lowest levels for both AER1 and AUAUL. Institutions classified as "other" show relatively high values of AER1 but not AUAUL. Cooperative banks show the highest average level of asset encumbrance when measured by AUAUL.

4.2 Regression analysis

Table 4 presents the summary statistics of the variables of study. The average value of the CDS spread variable is 5.14, corresponding to 171 basis points. The median value is 5.17, corresponding to 176 basis points. In terms of bank CAMELS indicators, we find that, on average, a sample bank has a tier 1 ratio of 0.15, a leverage ratio of 0.08, net loans to deposits and a short-term funding ratio of 0.77, a liquid assets to total assets ratio of 0.18. The average ratio of the loan-loss reserve to gross loans is 0.04, and the ratio of unreserved impaired loans to equity is 0.33. The average ROA and ROE are nearly 0. From all the control variables, central bank exposure presents the lowest standard deviation of 0.01.

[Table 4]

Table 5 reports the results of the baseline regressions. In all regressions, we control for country fixed effects and cluster errors by bank country-business-type. Country fixed effects are included in all models to help to control for factors affecting CDS premia at the country level, including regulatory particularities common to all banks of a country. To account for the potential correlation of the errors among the banks belonging to the same business category in a given country, we apply country-business model clustering in all our regression models. The latter restricts the inference to rather conservative conclusions in which, for example, German saving banks are effectively treated as one observation when assessing the statistical importance of the effects.

Models 1–3 include the three asset encumbrance measures as explanatory variables. A negative and significant association between banks' implied CDS spreads and asset encumbrance emerges across all models. Thus, our initial evidence suggests a net positive perception of creditors towards asset encumbrance. As suggested in the theoretical discussion, higher collateralisation could lead to a lower probability of default due to liquidity risks and, hence, reduce credit risk premiums.

While the coefficients for AER1 and AUAUL are highly significant, AER2 is significant only at the 10% level. An increase in AER2 is also associated with a lower decrease in CDS spreads when compared to AER1 and AUAUL. In contrast to AER1, AER2 reflects the encumbrance of OBS collateral. This finding could point to a more negative perception of on encumbrance of off-balance sheet collateral compared to on-balance assets. High levels of encumbered OBS collateral are characteristic of investment banks which engage in matched book trading, the activity of carrying large volumes of repos and reverse repos, effectively re-using collateral received to finance repo liabilities.

[Table 5]

In contrast to asset encumbrance ratios, the coefficients for capital and liquidity ratios turn out to be insignificant in all models. Variables such as asset encumbrance or asset quality seem to provide more valuable information on bank risk than capital and liquidity ratios. These results are consistent with recent literature pointing to a limited market reliance on capital and liquidity ratios to account for overall bank risk. Ötker-Robe and Podpiera (2010) find no significance in capital and liquidity ratios over the period 2004–2008 using a sample of 29 European Large Complex Financial Institutions (LCFI). Chiaramonte and Casu (2013), using a sample of 57 mostly European banks, find no statistical significance for Tier 1 and leverage and a limited statistical significance of liquidity ratios. Hasan, Liu, and G. Zhang (2016) also find no statistically significant relation with the Tier 1 capital or liquidity ratios using a sample of 161 global banks in 23 countries. Kanagaretnam, G. Zhang, and S. B. Zhang (2016) find in a sample of 27 U.S. Bank Holding Companies (BHC) that the capital ratio is not significantly related to CDS spreads.

The coefficients for the ratio of loan-loss reserve to gross loans ratio are all positive and highly significant. The higher this ratio, the lower the quality of the loan portfolio; and therefore an increase in loan loss reserves should lead to an increase in CDS spreads. This result is consistent with Hasan, Liu, and G. Zhang (2016) who also find a positive relationship between CDS spreads and the loan loss provision ratio.

The coefficients for the ratio of unreserved impaired loans to equity are all negative and significant on a 10% level. Banks with a higher value of this ratio exhibit higher impairments that have not been provisioned. Thus, this result implies that investors are not excessively concerned with such impairments. Chiaramonte and Casu (2013) also obtain this inverse relationship.

We observe opposing signs on the effects of ROA and ROE. The coefficients on ROA are all negative and highly significant. A negative sign for ROA could point to investors perceiving banks with a lower level of operating income relative to a level of investment as riskier. The coefficients for ROE are positive and highly significant, pointing to increased perceived default risk in institutions with higher profitability relative to their capital base. This result is somewhat surprising. Given the subdued profitability in traditional lending businesses in Europe, this finding could point to concerns by markets with banks that engage in highly profitable activities such as trade finance, invoice discounting or securities lending, with a comparatively low capital base. Relatedly, conditional on assets profitability, ROE may signal about bank's leverage: if traditional measures of leverage are not very infromative, one can observe positive CDS dependence on ROE when simultaneously controlling for asset profitability.

The coefficient on the ratio of central bank exposure to total assets turns out to be positive and significant, implying that reliance on central bank funding is positively associated with bank risk. Not surprisingly, credit quality is also strongly associated with lower CDS spreads. Negative and highly significant coefficients are obtained across all models. The coefficient for size turns out to be negative, pointing out to a size advantage. The ratio of off-balance sheet items to total assets and business model variables are not statistically significant.

Our second set of regressions explores the relationship between CDS spreads and key variables, including the interactions of asset encumbrance metrics with CAMEL, control variables, GIIPs and Nordic countries dummies. The results are presented in table 6. All models include the individual (non-interacted) CAMEL and control variables but for clarity these are not shown since the coefficients are very much in line with those presented in table 6.

We first discuss models 1 and 2 together as they yield very similar results. The stand-alone coefficients of asset encumbrance ratios (AER1 an AER2) are negative and significant. Several coefficients of the interacted CAMEL and control variables are statistically significant at the conventional levels, pointing to the existence of mediating effects in the relationship between asset encumbrance and CDS spreads. We first discuss the results for the interactions with control variables followed by CAMEL variables.

The coefficients for the interaction of asset encumbrance with the GIIPS and Nordic country dummies are significant and have opposite signs. GIIPS and Nordic countries present, on average, the highest levels of asset encumbrance in our sample. For GIIPS, the coefficient is positive, though, it is not large enough to offset the negative relationship between asset encumbrance and the bank risk arising from the main effect. This result indicates that for banks headquartered in economically weak countries the adverse effect of encumbrance coming from structural subordination may dominate its positive stable funding effect. For Nordic countries, the interaction coefficient is negative, i.e. it amplifies the average effect. This may reflect a positive perception towards asset encumbrance arising from the issuance of covered bonds that are typically considered very safe investments.

A positive and significant coefficient is obtained for the interaction with the ratio of central bank exposure to total assets. High asset encumbrance levels in banks with high amounts of central bank funding are negatively perceived by investors. For banks with high levels of central bank exposure (the maximum of which is 0.12 in our sample), the positive effect of the interaction term offsets the negative effect of the stand-alone asset encumbrance coefficient, thus making higher levels of encumbered assets detrimental in absolute terms. This goes well in line with the theoretical model as dependence on central bank funding may indicate worse financial conditions of a bank and, hence, higher collateral haircuts that it faces in the private markets.

[Table 6]

A negative and significant coefficient is found for the interaction with the ratio of loan loss reserves to gross loans. Although higher loan loss reserves may point to a lower quality of the loan portfolio, excess reserves may signal a lower probability of incurring unexpected losses in the future and may therefore be perceived positively by markets. A positive and significant coefficient, however, is found for the interaction with the unreserved impaired loans to equity ratio. This could point to concerns by investors in banks with large amounts of encumbered assets that lack the reserves to deal with future loan defaults.

The coefficients for the interactions of asset encumbrance with the Tier 1 capital and leverage ratios have conflictive signs, negative and positive, although the former turns out to be not significant. The leverage ratio is a non-risk-based measure of capital adequacy. A high value of the leverage ratio accompanied by larger amounts of encumbered assets could point to increasing risk in the loan portfolio which in turn would point to higher overall bank risk. Similarly to central bank exposure, the positive effect of the interaction term may offset the negative effect of the stand-alone asset encumbrance coefficient, thus making higher levels of encumbered assets detrimental in absolute terms.

Model 3 presents the results for AUAUL. While the stand-alone coefficient of AUAUL ratio turns out to be not significant, the coefficients corresponding to the interaction with the loan loss reserves to gross loans ratio and the Nordics dummy are both significant and of a negative sign. Consistent with the results of models 1 and 2, banks with high levels of asset encumbrance and with high levels of loan loss provisions, or based in Nordic countries, could benefit from increasing their levels of asset encumbrance. The effects of the remaining interacted variables are less significant but almost all, including central bank exposure and GIIPS, conserve the same sign found for models 1 and 2.

5 Conclusion

Asset encumbrance has been a much-discussed subject in recent literature and policymakers have been actively addressing what some regulators consider to be excessive levels of asset encumbrance. In this paper, we provide a theoretical model that captures the relationship between asset encumbrance and bank liquidity risk. According to this model, secured funding serves as a mechanism that change bank's exposure to liquidity risks. When the degree of over-collateralization is not high, a bank can fully exploit the stability of secured financing and reduce its liquidity risks associated with the unsecured debt holders. Hence, asset encumbrance and risk premiums would have a negative relationship.

In an alternative situation when a bank faces high rates of over-collateralization, asset encumbrance can have an opposite effect on bank's liquidity risk. In this case, as collateralization requires relatively large amount of pledgeable assets, the negative structural subordination effect dominates the positive impact of asset encumbrance. Hence, the relationship between encumbrance and bank risk premiums can be positive when a bank faces adverse conditions of collateralization.

We next provide empirical analysis that supports the theoretical predictions. We show that asset encumbrance is, on average, negatively associated with bank risk across different asset encumbrance measures. We also show that certain bank-level variables play a mediating role in the relationship between asset encumbrance and bank risk. Thus, for banks that have a high exposure to the central bank, high levels of unreserved impaired loans, high leverage ratio or located in southern Europe, larger amounts of encumbered assets and encumbered OBS collateral are less beneficial and could even be detrimental in absolute terms. Banks with high levels of loan loss provisions or based in Nordic countries, in contrast, benefit from increased levels of asset encumbrance. These results suggest that regulators need to be cautious before leaping to all-encompassing conclusions when assessing the effects of asset encumbrance levels.

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A Appendix: Proofs

Proof of proposition 1

From equation (2), we have

$$(1-s)D_u = \theta^* + k\phi - s$$

Substituting $(1-s)D_u$ into the participation constraint (3), we get:

$$k\phi - s + \int_0^{\theta^*} \theta dF(\theta) + \int_{\theta^*}^{\bar{\theta}} \theta^* dF(\theta) = (1-s)(1+\gamma)$$

Differentiating this equation with respect to s, one gets:

$$\frac{\partial\theta^*}{\partial s} = -\frac{\gamma}{1-F(\theta^*)}$$

Under the assumption of uniform distribution of θ one can solve for θ^* explicitly:

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma-s\gamma-k\phi)}$$

Clearly, $\partial\theta^*/\partial s < 0$.

Q.E.D

Proof of proposition 2

We just need to show that the derivative of Π with respect to s is positive. Coupled with the participation constraint (3), the bank expected profit can be rewritten as:

$$\Pi = \int_0^{\bar{\theta}} \theta dF(\theta) - s - (1-s)(1+\gamma) + k\int_{\theta^*}^{\bar{\theta}} dF(\theta) + k\phi\int_0^{\theta^*} dF(\theta).$$

By differentiating this equation with respect to s one gets:

$$\frac{\partial\Pi}{\partial s} = \gamma + k(\phi-1)f(\theta^*)\frac{\partial\theta^*}{\partial s} = \gamma\Big[1 + k(1-\phi)\frac{f(\theta^*)}{1-F(\theta^*)}\Big],$$

or under the assumption of uniform distribution of θ:

$$\frac{\partial\Pi}{\partial s} = \gamma + \frac{k\gamma(1-\phi)}{\sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma-s\gamma-k\phi)}}.$$

Clearly, $\partial\Pi/\partial s > 0$.

Q.E.D

Proof of proposition 3

Under the assumption $h = \phi^{-1} - 1$ and uniform distribution of θ, the liquidity cutoff θ^* at the optimum s^* can be rewritten as

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}.$$

Under the similar assumptions, the definition of the liquidity cutoff simplifies to:

$$\theta^* = (1-s^*)D_u.$$

Combining the two, one gets:

$$D_u = \frac{\bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}}{1-s^*}.$$

Taking the derivative of D_u with respect to s^*, one gets

$$\frac{\partial D_u}{\partial s^*} = \frac{\bar{\theta}(1+\gamma)(1-s^*) + \bar{\theta}\sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)} - \bar{\theta}^2}{(1-s^*)^2}.$$

Hence, for $\partial D_u / \partial s^*$ to be negative it suffices to show that

$$\sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)} < \bar{\theta} - (1+\gamma)(1-s^*),$$

which is true since

$$\begin{aligned}\bar{\theta} - (1+\gamma)(1-s^*) &= \sqrt{(\bar{\theta} - (1+\gamma)(1-s^*))^2} \\ &= \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*) + (1+\gamma)^2(1-s^*)^2} \\ &> \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}.\end{aligned}$$

Q.E.D

Proof of proposition 4

If the bank wants to issue s secured debt, the bank needs to pledge $(1+h)s$ collateral to the secured debt holders. As before, given s, we can solve θ^* and D_u. The procedures are exactly the same as previous sections.

First, define a critical liquidity return for the bank:

$$\theta^* = (1-s)D_u - k\phi + (1+h)\phi s$$

Then we can solve θ^*

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}((1+\gamma)(1-s) - k\phi + (1+h)\phi s)}$$

Clearly, $\partial\theta^*/\partial s > 0$ if $(1+h)\phi > 1+\gamma$.

Q.E.D

B Appendix: Definitions and Sources of Asset Encumbrance

In this section we review the definitions of asset encumbrance and describe how assets become encumbered. We also review the most common sources of asset encumbrance (i.e. the liabilities or obligations that give rise to encumbered assets).

B.1 Defining asset encumbrance

European regulations define encumbered assets as "*assets pledged or subject to any form of arrangement to secure, collateralize or credit enhance any transaction from which it cannot be freely withdrawn*".[11] The Basel Committee on Banking Supervision (BCBS) defines unencumbered assets as those assets which are "*free of legal, regulatory, contractual or other restrictions on the ability of the bank to liquidate, sell, transfer, or assign the asset*".[12]

To clarify the definition of encumbrance, let us consider a bank (Bank A) whose assets include loans and a portfolio of securities (government or corporate bonds, equities, etc.), financed via equity capital, retail deposits and unsecured wholesale funding, as shown in the left hand side of figure 10. Bank A could obtain additional funding from a counterparty, let us say Bank B, by entering into a secured financing transaction, as shown in the right hand side of figure 10. Under such arrangement Bank A provides collateral to Bank B in order to mitigate the risk of failing to keep interest repayments or repaying the borrowings. In exchange, Bank A benefits from cheaper funding when compared to an equivalent unsecured transaction.[13] The arrangement imposes restrictions to Bank A on its ability to sell, transfer or dispose of the collateral provided during the term of the transaction. Bank A would consider such assets encumbered.

[Figure 10]

Figure 10 represents the securities provided as collateral as recorded or recognised in Bank A's balance sheet rather than being transferred to Bank B's balance sheet. Collateral obtained by Bank B is therefore represented in an off-balance sheet (OBS) rather than an on-balance sheet, and is known as "OBS collateral" or simply "collateral received". The assumption that the collateral remains recognised from Bank A's balance sheet is a necessary condition for being considered an encumbered asset of Bank A. If the assets used as collateral were derecognised

[11] See European Commission (2015).

[12] See BCBS (2013)

[13] In addition, the arrangement may provide for savings in regulatory capital requirements to Bank B as well as lower regulatory liquidity requirements to Bank A and Bank B.

by Bank A then they would be recognised by Bank B and they would not be encumbered for Bank A.

In practice, the recognition or derecognition of collateral provided depends on the contractual terms of the transaction as well as its accounting treatment. Derecognition cannot occur unless the securities are transferred to the counterparty. This can be achieved by using "title transfer" arrangements, whereby full ownership of the collateral is passed on to the counterparty during the term of the transaction.[14] Collateral can also be provided under "security interest" arrangements, which do not transfer ownership but concede rights to the counterparty to obtain full ownership of the collateral under some pre-determined event, such as failure to repay.[15] The use of one technique over the other depends on market practice. Collateral provided in secured financing transactions such as repurchase agreements (i.e. repo) is typically provided by way of title transfer whereas collateral used as a margin for OTC derivatives can be provided using both methods.[16]

The transfer of title over collateral, however, is not a sufficient condition for derecognition to occur, with the actual outcome depending on the applicable accounting treatment. Under International Financial Reporting Standards (IFRS), IAS 39 applies a set of tests to assess whether (i) the risks and rewards and (ii) control over the asset have been transferred.[17] If the risks and rewards have not been transferred, or in other words, if the collateral provider continues to be exposed to the risks of ownership of the assets such as loss in market value and/or the benefits that they generate such as dividends, then the collateral would remain recognised on its balance even if a transfer of assets has occurred. But even if the risks and rewards had been transferred, further control tests are undertaken to understand which entity controls the asset. If the collateral provider could direct how the benefits of that asset are realised, then the collateral would not be derecognised either.

As illustrated in figure 10, the value of securities that Bank A posted as collateral is higher than the value of the borrowings. This practice is known as overcollateralisation and is intended to mitigate the risk of the collateral falling in value during the term of the transaction. It is usually undertaken by means of a "haircut" or "margin ratio".[18] Collateral agreements often

[14]Under title transfer, Bank B would have to return the collateral (or equivalent securities) to Bank A when the original transaction matures.

[15]Security interest arrangements are also known as collateral pledges.

[16]Under English Law the collateral for OTC derivatives is typically provided by way of title transfer, whereas under New York Law collateral is typically provided under security interest.

[17]The treatment under US GAAP (ASC 860) differs from IFRS since the focus is on whether the transferor has surrendered control over a financial asset.

[18]The agreed haircut or margin ratio determines the percentage by which the market value of a security is reduced for the purpose of calculating the amount of collateral being provided.

require a frequent (sometimes daily) marked-to-market valuation of the collateral and requests to top up the value of collateral, known as collateral calls, may be triggered if its market value falls below certain pre-determined threshold amounts.

Even in the case in which the collateral received is not reflected in its balance sheet, Bank B could reuse some or all of the collateral received from Bank A to obtain financing from a third party (let us say, Bank C). As illustrated in figure 11, this re-use of collateral by Bank B would result in the encumbrance of OBS collateral. As such, encumbrance can affect both on-balance sheet assets as well as OBS collateral. The practice of providing collateral that has been previously received is known as collateral re-use or re-hypothecation. It is common practice and may result in long "collateral chains".[19].

[Figure 11]

B.2 Sources of asset encumbrance

The liabilities or obligations that give rise to encumbered assets are known as "sources of asset encumbrance" or "matching liabilities". The typical bank will have encumbered assets from several sources but the simplest institutions may rely only on a single source or may present no encumbered assets at all. We now discuss some of the most common sources of asset encumbrance.[20]

B.2.1 Secured financing transactions

Secured financing transactions encompass myriad transactions involving the temporary provision of securities to borrow cash or other securities. Common types include repurchase agreements (repos), buy/sell backs or securities borrowing and lending. Collateral in repo is provided under a title transfer but it remains recognised in the balance sheet of the collateral provider's

[19] The terms re-hypothecation and re-use are often used interchangeably and we will do so here. In practice there are legal distinctions between them that may be relevant in a different context. Recent studies have analysed the concept of re-hypothecation and "collateral velocity". Analytical work includes Adrian and Shin (2010) and Singh (2010) More recent work has focussed on liquidity mismatches and the role of collateral in intermediation chains. Brunnermeier and Krishnamurthy (2014) introduced the Liquidity Mismatch Index (LMI) which compares the market liquidity of assets and the funding liquidity of liabilities, thus capturing the length of collateral intermediation chains.

[20] In addition to the sources covered in this section, transactions that may result in encumbered assets include collateral swaps, also known as collateral upgrade transactions, where collateral of a different quality is exchanged. Collateralised guarantees rely on securities to secure an existing or future liability. Other arrangements, such as factoringwhich include the transfer of trade receivables to an institutionmay result in similar encumbrance to securitisations.

(i.e. the repo seller) since the risks and rewards of the collateral are retained.[21] Thus, repo collateral is encumbered for the collateral provider. Encumbered assets in repo are predominantly government bonds, followed by corporate bonds and covered bonds. Asset-backed securities and equities are also used as collateral. Most of the funding provided by central banks is transacted through repo. Like Dexia, many European banks were, and some still are, heavily reliant on repo financing from the ECB.

B.2.2 Asset-backed securities (ABS) and mortgage-backed securities (MBS)

Another potential source of asset encumbrance is securitisations. These entail ABS and MBS bonds or notes being issued and receivables, which may include retail or commercial mortgages in MBS, or credit card debt or other loans in ABS, being used as collateral.

A traditional two-step securitisation involves the initial transfer of the receivables of the originating bank to a Special Purpose Vehicle (SPV) and the sale of the ABS or MBS to investors. The overall securitisation structure is intended to make sure that there is a true sale of receivables to the SPV and that the SPS is "bankruptcy remote". Accounting standards however, may require that the SPV is consolidated into the "sponsoring" bank balance sheet, including all of its assets and liabilities, even the receivables.[22] If the underlying receivables were consolidated, this would result in the recognition of such receivables on the sponsor's balance sheet. However, tests to assess whether the assets meet the criteria for accounting derecognition, as discussed earlier, shall still be undertaken. If derecognition criteria are not met the receivables would be encumbered. This is often the case since it is common for the sponsoring bank to keep an active role in the securitisation, for example, by servicing the assets or providing support by retaining certain tranches to absorb first losses and potential risks in relation to timings in the collection of the receivables.

ABS or MBS can be used as collateral to raise funding with counterparties and central banks. Thus, a common practice across some banks, especially during the Eurozone crisis, is the retention of their self-issued ABS or MBS rather than its sale to investors.[23] If notes are retained, they would not be encumbered. But if the notes are used to raise fresh funding, for

[21] If this was not the case, banks could artificially reduce its overall leverage by derecognising collateral in repurchase agreements. This treatment was exploited by Lehman Brothers under the well-known "Repo 105" scheme, characterised by the New York Attorney General Andrew Cuomo as a "massive accounting fraud" and leading to a review by the accounting standard settlers of the accounting treatment of repo transactions.

[22] The consolidation models under IFRS and GAAP are relatively similar and are based on the criteria of entity control over the SPV.

[23] The acceptance of securitised notes as collateral in the ECB facilities led to an important increase in retention levels during the Eurozone crisis, with overall retention as a proportion of total gross issuance increasing from 26% in the first half of 2007 to 42% in the first half of 2012 (IMF (2013)).

example, from the central bank via repo, the receivables would become encumbered as it occurs in securities financing transactions.

Figure 12 (left-hand side) illustrates how securitised receivables can be encumbered (highlighted in green) by collateralising ABSs that are either (i) sold to investors or (ii) used as repo collateral to obtain funding from another counterparty.

[Figure 12]

B.2.3 Covered bonds

Covered bonds are similar to MBS but the mortgages used as collateral always remain recognised on the consolidated balance sheet of the issuing entity and thus always generate encumbrance. The issuer and the investors have dual recourse to the collateral. This feature, together with the existence of overcollateralisation requirements and the dynamic replenishment of non-performing loans in the collateral pool imply that these instruments are perceived as being very safe. There is indeed no known default on covered bonds since their inception.

The use of covered bonds as collateral has significantly increased in recent times. For many banks in peripheral European countries (GIIPS) funding collateralised by retained covered bonds became the main source of long-term funding during the Eurozone sovereign crisis, as their access to unsecured markets was partially or fully closed (Van Rixtel and Gasperini (2013)).

B.2.4 Derivatives

Derivatives also generate encumbrance, as collateralisation has become a key method of mitigating counterparty credit risk in derivative markets, both on over-the-counter (OTC) and exchange-traded (ETD) derivatives. Collateralisation occurs because of the provisioning of the margin, in two different forms. A variation margin is posted during the course of the transaction to cover adverse changes in value (i.e. a negative mark-to-market value). Initial margin (also known as an independent amount) is posted at the beginning of a transaction to cover potential future adverse changes in the value of the contract, and is recalculated on a regular basis.

The margin provided is subject to restrictions and therefore constitutes encumbered assets. This is illustrated in figure 12 (right-hand side).[24] The margin can be provided in the form

[24] The figure assumes that the variation margin is not offset against the derivative liability (i.e. the negative fair value from the derivative) therefore becoming encumbered. Some contracts allow for such an offsetting of the variation margin. The outstanding exposure between the counterparties is settled and the terms of the derivative contracts are reset so that the fair value is zero, leading to no encumbered assets due to an exchange of the variation margin.

of cash or securities and it is common to provide re-hypothecation rights to the counterparty. According to the latest ISDA Margin Survey, for non-cleared OTC derivatives cash represents 76.6% of the collateral provided, followed by government bonds (13.4%) and other securities (10.1%), including US municipal bonds, government agency/government-sponsored enterprises (GSEs), and equities (ISDA (2015)).

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Figure 1: Bank Available Collateral k and Unsecured Debt Interest Rate

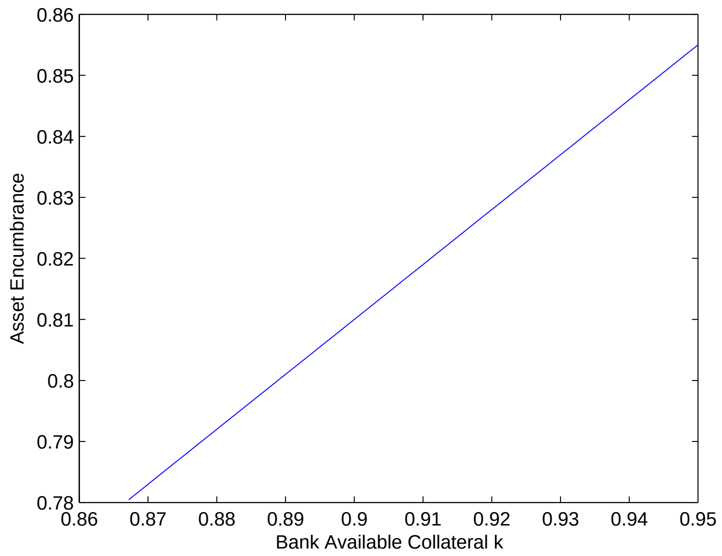


Figure 2: Bank Available Collateral k and Asset Encumbrance

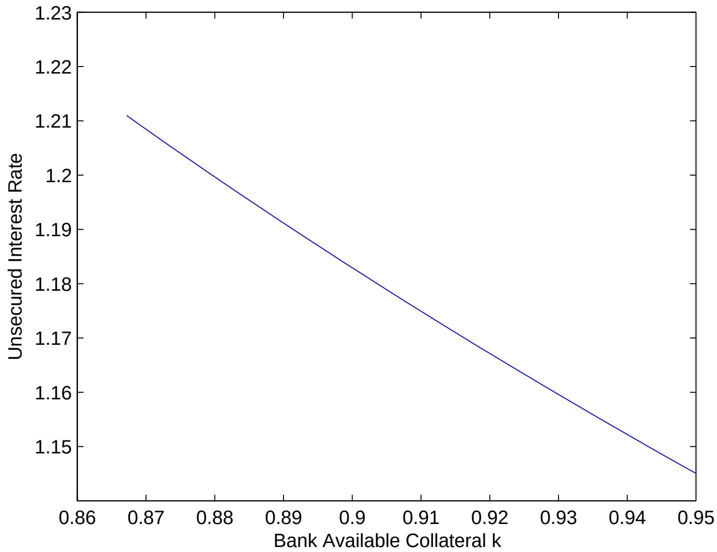


Figure 3: Asset Encumbrance and Unsecured Debt Interest Rate

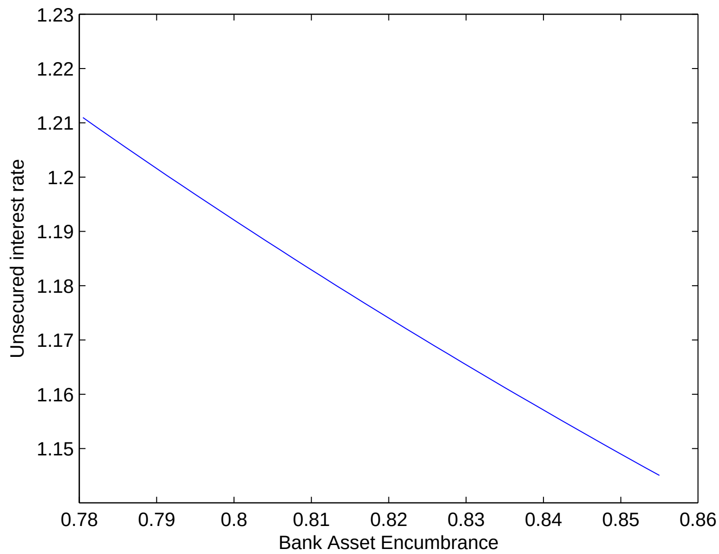


Figure 4: Bank Asset Encumbrance and Liabilities Subject to Run/Unencumbered Asset

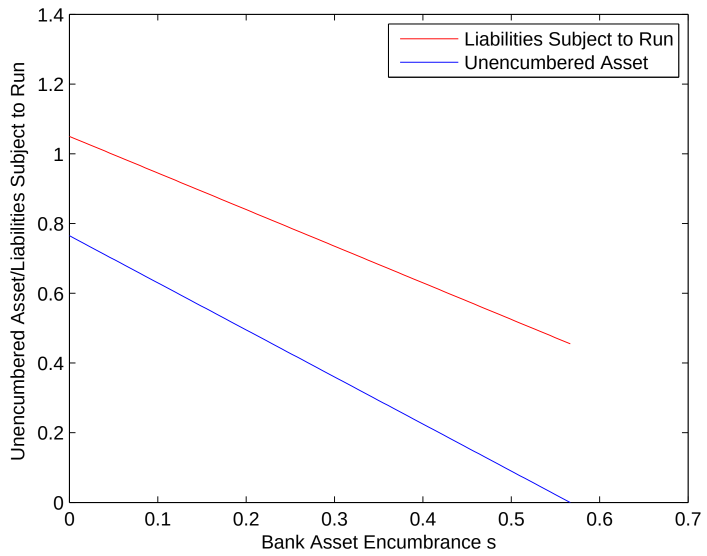


Figure 5: Bank Available Collateral k and Unsecured Debt Interest Rate

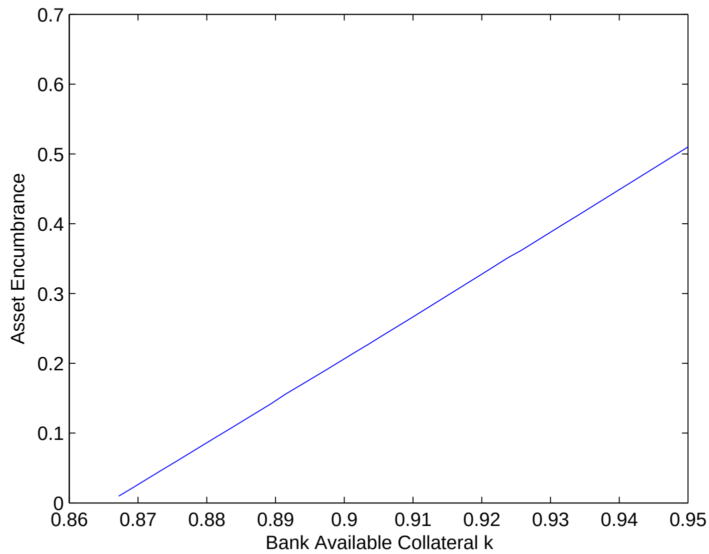


Figure 6: Bank Available Collateral k and Asset Encumbrance

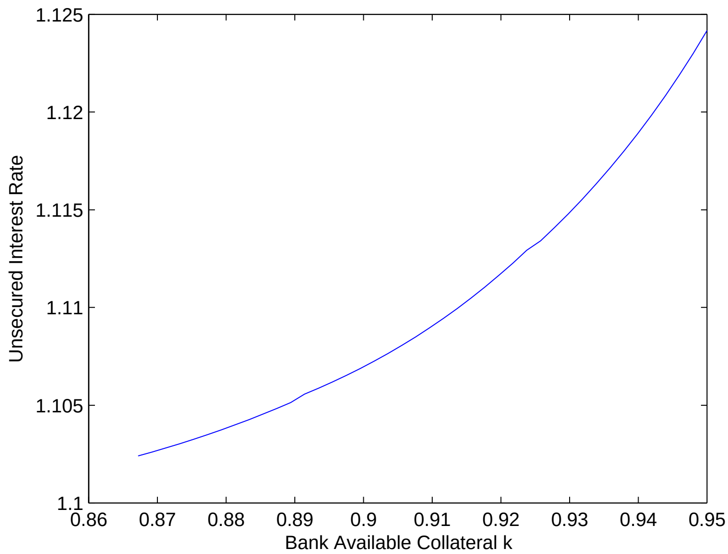


Figure 7: Asset Encumbrance and Unsecured Debt Interest Rate

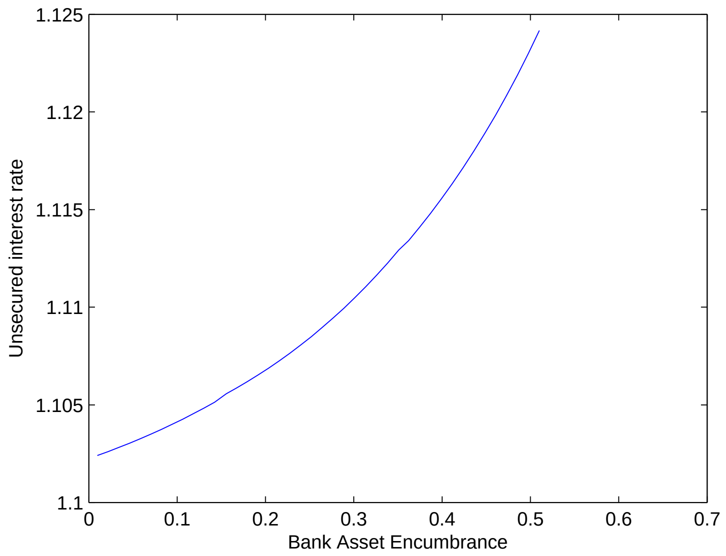


Figure 8: Asset encumbrance metrics

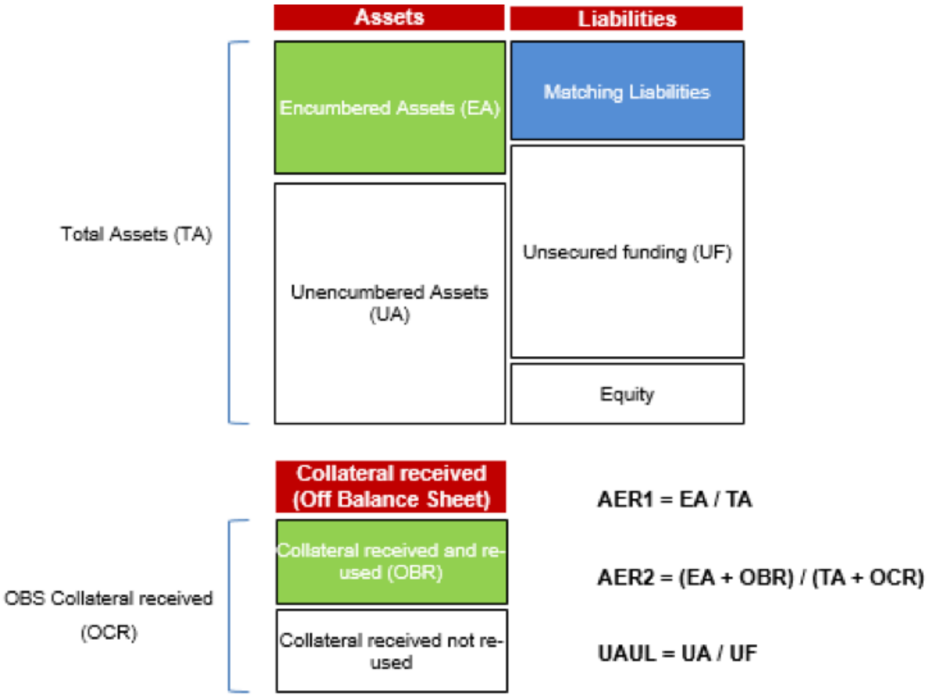


Figure 9: Average asset encumbrance by country

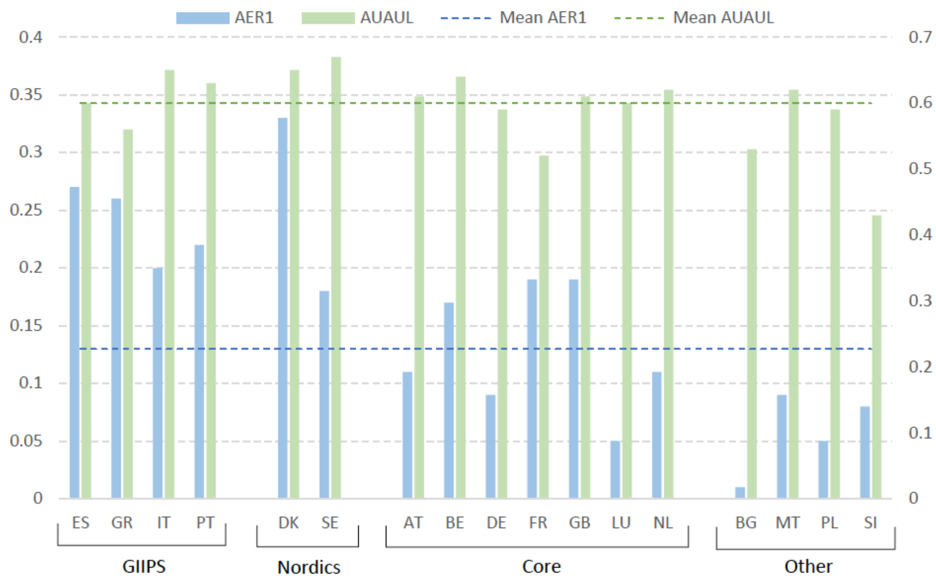


Figure 10: Encumbrance of assets when obtaining secured funding

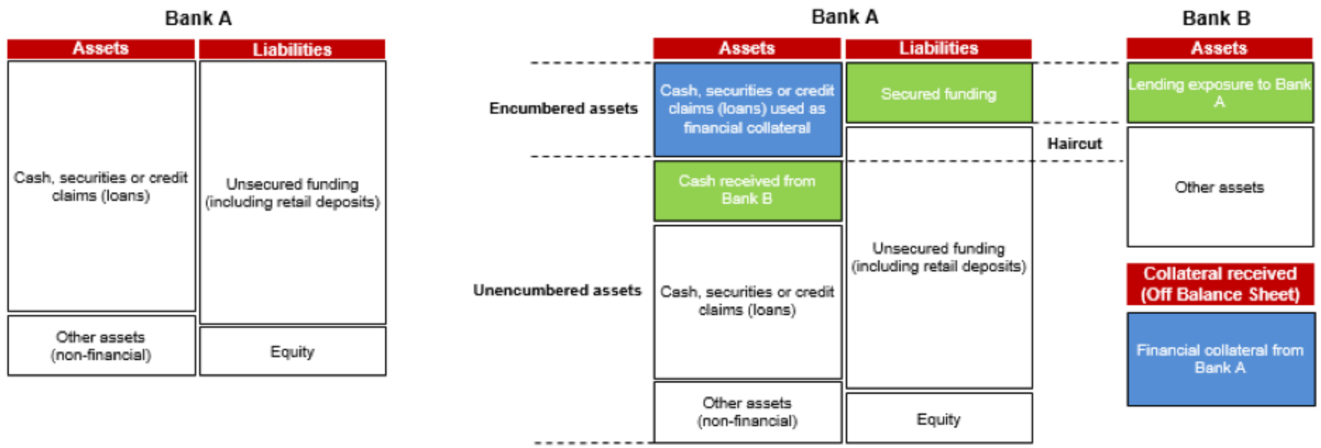


Figure 11: Collateral received and re-used

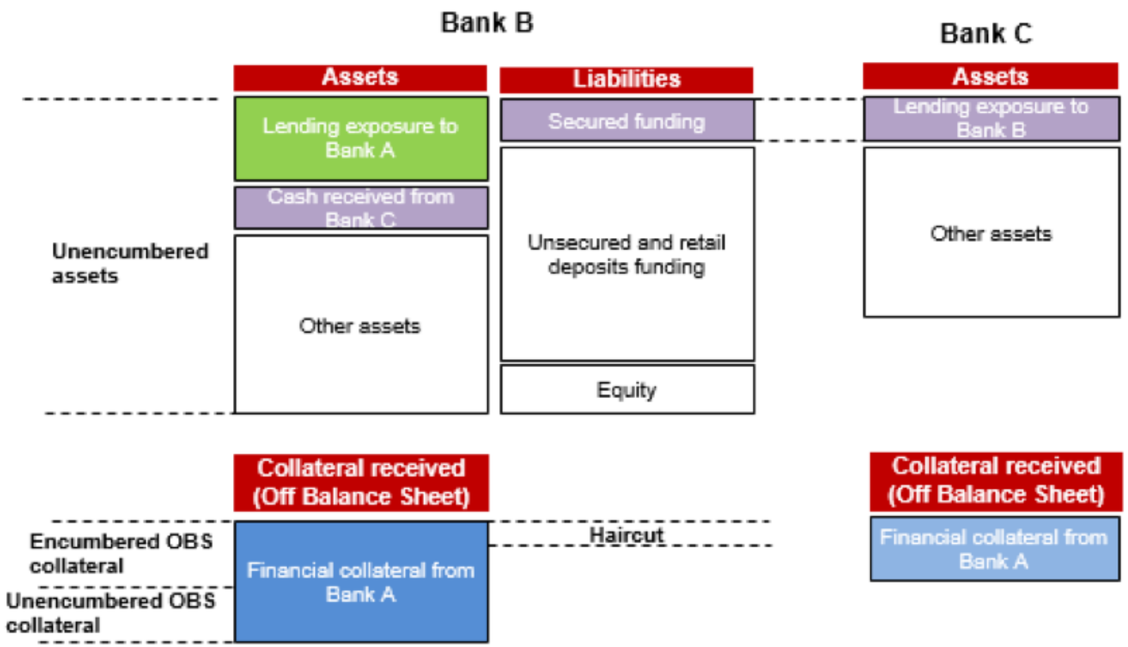
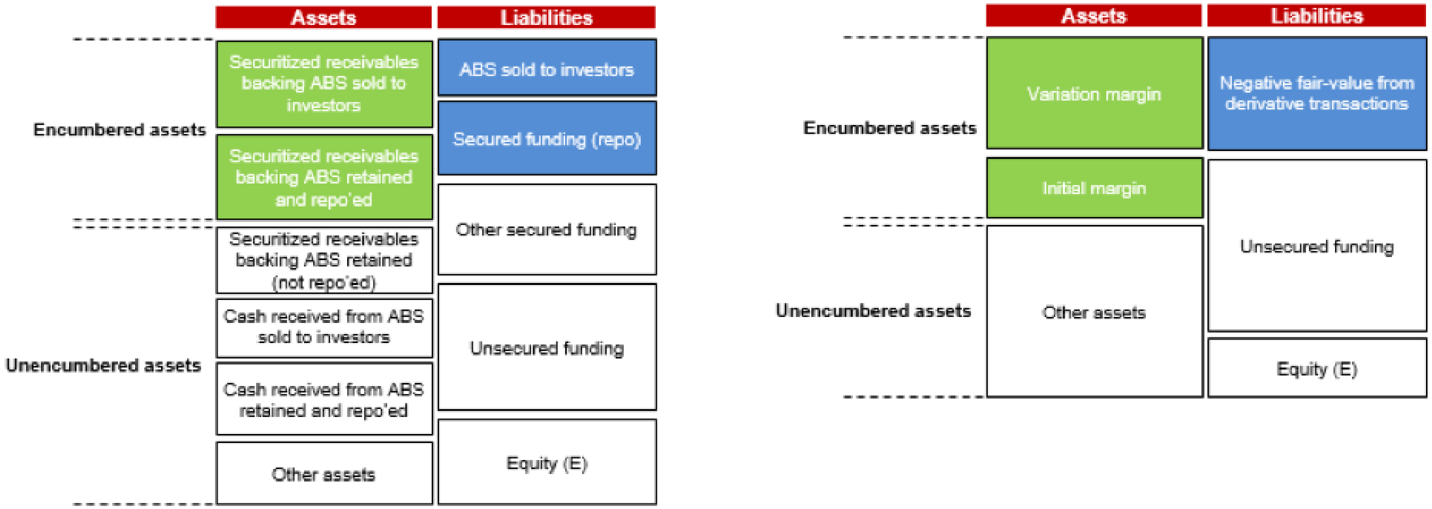


Figure 12: Encumbered and unencumbered assets from securitization and derivative transactions



List of Tables

Table 1: Summary statistics of asset encumbrance metrics

	Mean	Median	SD	Min	Max
AER1	0.13	0.09	0.11	0.00	0.68
AER2	0.14	0.10	0.12	0.00	0.70
AER3	0.60	0.59	0.08	0.00	1.00

Table 2: Correlation matrix of asset encumbrance metrics

	AER1	AER2	AER3
AER1	1		
AER2	0.974^{***}	1	
AER3	0.388^{***}	0.363^{***}	1

Table 3: Average levels of asset encumbrance, by bank groups

	AER1	AER2	AER3
By credit rating			
A/B	0.08	0.08	0.61
B	0.15	0.16	0.61
B/C	0.12	0.13	0.60
C	0.13	0.14	0.60
C/D	0.13	0.14	0.62
D	0.12	0.13	0.63
D/E	0.14	0.14	0.50
E/F	0.03	0.03	0.57
By bank size			
$<$ €3.5bn	0.10	0.11	0.60
€3.5–15bn	0.12	0.13	0.60
€15–50bn	0.19	0.19	0.63
€50–170bn	0.25	0.25	0.56
€170–600bn	0.27	0.28	0.65
$>$ €600bn	0.15	0.20	0.58
By bank type			
BHC & Commercial	0.18	0.19	0.61
Cooperative	0.14	0.14	0.62
Saving	0.09	0.10	0.56
Other	0.22	0.22	0.61

Table 4: Summary statistics, variables of study

	Mean	Median	SD	Min	Max
*ln*CDS	5.14	5.17	0.33	4.56	6.56
CAMEL variables					
Tier 1 Ratio	0.15	0.14	0.04	0.05	0.35
Leverage ratio (Equity / TA)	0.08	0.08	0.02	0.01	0.18
Net loans to deposits and ST funding	0.77	0.75	0.24	0.05	2.05
Liquid assets / TA	0.18	0.11	0.23	0.01	2.98
Loan loss reserves / gross loans	0.04	0.02	0.04	0.00	0.27
Unreserved impaired loans / equity	0.33	0.14	0.49	0.00	4.63
ROA	0.00	0.00	0.01	−0.04	0.03
ROE	0.01	0.02	0.10	−1.08	0.32
Control variables					
Central bank exposure / TA	0.01	0.01	0.01	0.00	0.12
OBS / TA	0.08	0.06	0.10	0.00	1.66
Investment grade	0.66	1.00	0.47	0.00	1.00
BHC and commercial banks	0.19	0.00	0.39	0.00	1.00
Saving and cooperative banks	0.75	1.00	0.43	0.00	1.00
Size	6.75	6.41	0.84	6.00	9.32
GIIPS	0.28	0.00	0.45	0.00	1.00
Nordics	0.02	0.00	0.15	0.00	1.00

Table 5: Baseline results

	(1)	(2)	(3)
AER1	-0.177^{***}		
	(0.06)		
AER2		-0.131^{*}	
		(0.07)	
AER3			-0.267^{***}
			(0.10)
Tier 1 Capital Ratio	1.058	1.046	1.103
	(0.93)	(0.92)	(0.92)
Leverage Ratio	-1.164	-1.102	-1.195
	(1.42)	(1.40)	(1.52)
Net loans to deposits & ST funding	-0.049	-0.053	-0.055
	(0.04)	(0.04)	(0.04)
Liquid assets	-0.105	-0.103	-0.108^{*}
	(0.07)	(0.07)	(0.06)
Loan loss reserves	1.927^{***}	1.959^{***}	2.085^{***}
	(0.61)	(0.64)	(0.62)
Unreserved impaired loans	-0.060^{*}	-0.062^{*}	-0.063^{*}
	(0.03)	(0.03)	(0.03)
ROA	-16.398^{***}	-16.369^{***}	-17.019^{***}
	(4.92)	(4.91)	(4.78)
ROE	0.538^{***}	0.528^{***}	0.555^{***}
	(0.18)	(0.18)	(0.17)
Investment grade	-0.466^{***}	-0.466^{***}	-0.464^{***}
	(0.02)	(0.02)	(0.02)
BHC and commercial	0.035	0.039	0.050
	(0.05)	(0.05)	(0.05)
Saving and cooperative	-0.007	-0.002	0.002
	(0.05)	(0.05)	(0.05)
Central bank exposure	1.150^{**}	1.171^{**}	1.190^{**}
	(0.56)	(0.55)	(0.53)
OBS / TA	0.077	0.073	0.072
	(0.09)	(0.09)	(0.08)
Size	-0.149^{***}	-0.149^{***}	-0.157^{***}
	(0.02)	(0.02)	(0.02)
Country FE	y	y	y
R^2	0.79	0.79	0.79
N observations	367	367	367
Nclusters	50	50	50

The dependent variable in all models is *ln*CDS. Standard errors (in parenthesis) are clustered by country-business type of bank. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Heterogeneous effects of asset encumbrance

	(1)	(2)	(3)
AER	-0.712^{***}	-0.605^{***}	-0.552
	(0.19)	(0.21)	(0.48)
AER $\times$			
Tier 1 Capital Ratio	-5.500	-5.182	3.596
	(4.97)	(4.83)	(2.95)
Leverage Ratio	15.409^{**}	15.180^{**}	2.751
	(6.03)	(6.42)	(4.81)
Net loans to deposits & ST funding	0.522^{***}	0.554^{***}	0.172
	(0.16)	(0.17)	(0.34)
Liquid assets	0.845^{**}	0.978^{**}	-0.358
	(0.38)	(0.41)	(0.51)
Loan loss reserves	-12.749^{***}	-11.524^{***}	-8.465^{***}
	(3.66)	(3.49)	(3.15)
Unreserved impaired loans	0.650^{**}	0.595^{**}	0.553
	(0.29)	(0.30)	(0.57)
ROA	15.780	28.157	-52.962
	(29.44)	(36.22)	(67.71)
ROE	-0.430	-1.059	2.658
	(1.41)	(1.83)	(4.32)
Central bank exposure	10.914^{**}	8.900^{*}	9.887
	(4.16)	(4.65)	(10.08)
OBS	-0.012	-0.119	3.054
	(0.82)	(0.81)	(2.15)
Size	0.125	0.073	-0.061
	(0.16)	(0.16)	(0.29)
Investment grade	0.348^{*}	0.351^{*}	0.317
	(0.20)	(0.20)	(0.19)
GIIPS	0.671^{***}	0.466^{**}	0.068
	(0.17)	(0.22)	(0.41)
Nordics	-0.466^{**}	-0.712^{**}	-1.236^{***}
	(0.21)	(0.27)	(0.41)
BHC and commercial	0.048	0.146	0.404
	(0.19)	(0.23)	(0.46)
Saving and cooperative	0.234	0.262	0.539
	(0.18)	(0.19)	(0.32)
Country FE	y	y	y
R^2	0.81	0.81	0.80
N observations	367	367	367
N clusters	50	50	50

The dependent variable in all models is *ln*CDS. Standard errors (in parenthesis) are clustered by country-business type of bank. All continuous explanatory variables are demeaned. All estimates are conditioned on a set of non-interacted control variables similar to Table 5 (not reported). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$